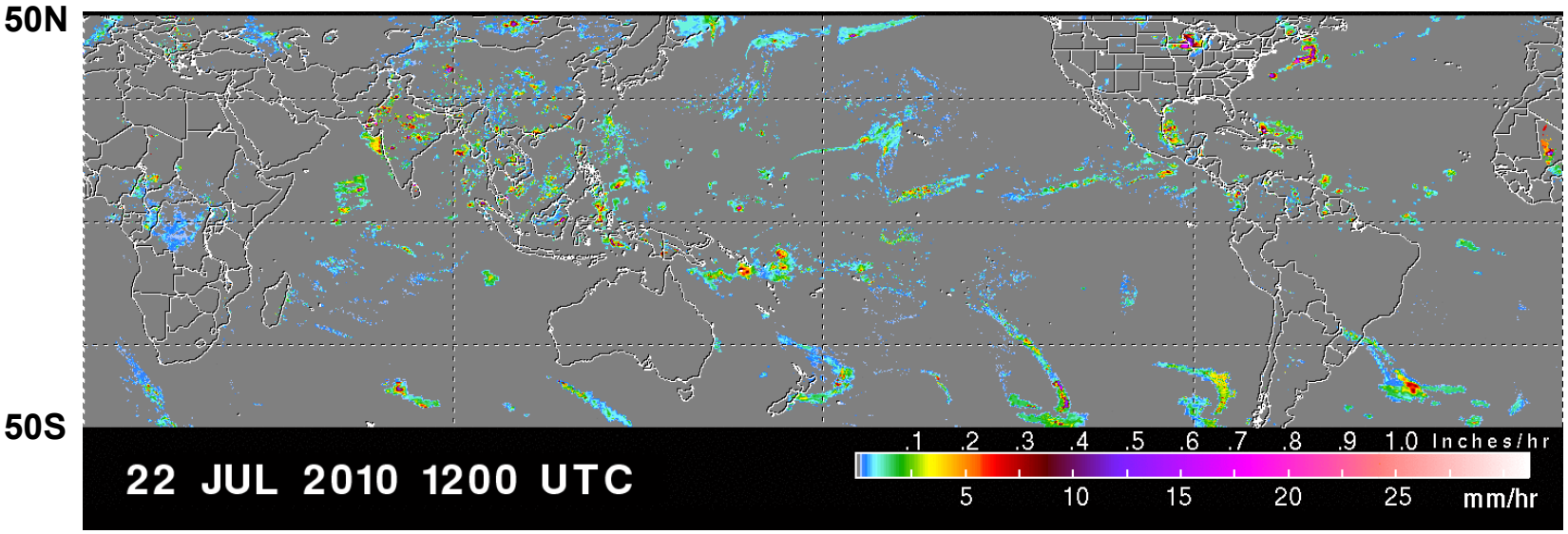
Next-Generation Global Precipitation Products and Their Applications

Borrowed from
Arthur Y. Hou
NASA Goddard Space Flight Center

Current Generation of Global Precipitation Products

Current multi-satellite products are based on MW or MW+IR observations from *uncoordinated* satellite missions using a variety of merging techniques

TRMM Realtime 3hr global rain map at 0.25° resolution



- TRMM radar/radiometer system provided an anchor for rainfall estimates by passive microwave sensors in the tropics and subtropics.
- Further improvements will require better spaceborne sensors and inversion algorithms (especially for light rain and falling snow).

The Global Precipitation Measurement (GPM) Mission

An international satellite mission specifically designed to deliver "next-generation" precipitation observations from space for research and applications.

Key to Better Global Precipitation Data Products:

- *Accuracy of instantaneous precipitation estimate*
- *Spatial coverage & temporal sampling (for improved estimation of precipitation accumulation)*
- *Spatial resolution (for local-scale applications)*
- *Data latency (for near real-time operational use)*

GPM Mission Concept

Unify and advance global precipitation measurements from space using a constellation of research and operational microwave sensors

Low Inclination Observatory (40º)

GMI (10-183 GHz)
(NASA & Partner, 2014)

- Enhanced capability for near-realtime monitoring of hurricanes & midlatitude storms
- Improved accuracy in rain accumulation

Partner Satellites:

GCOM-W1

DMSP F-18, F-19/20

Megha-Tropiques

MetOp, NOAA-19

NPP, JPSS (over land)

GPM Core Observatory (65º)

DPR (Ku-Ka band)
GMI (10-183 GHz)
(NASA-JAXA, LRD 2013)

- Precipitation physics observatory
- Transfer standard for inter-satellite calibration of constellation sensors

Key Contribution

Refine constellation sensor retrievals within a consistent framework to provide next-generation global precipitation data products

Coverage & Sampling

- 1-2 hr revisit time over land
- < 3 hr mean revisit time over 90% of globe

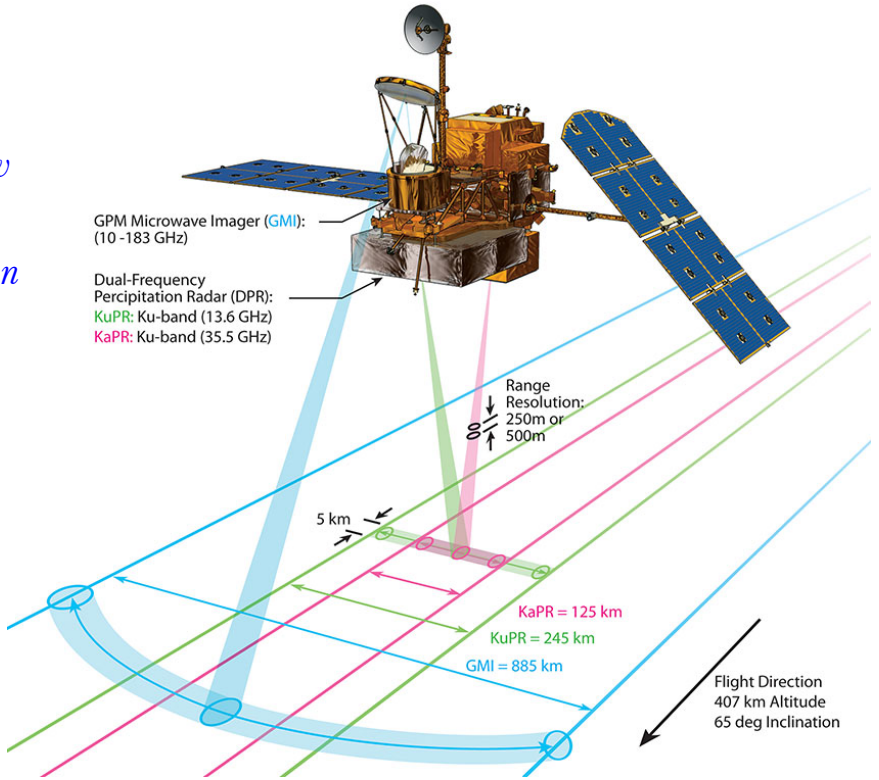
Core Observatory Measurement Capabilities

Dual-Frequency (Ku-Ka band) Precipitation Radar (DPR):

- *Increased sensitivity (~12 dBZ) for light rain and snow detection relative to TRMM*
- *Better measurement accuracy with differential attenuation correction*
- *Detailed microphysical information (DSD mean mass diameter & particle no. density) & identification of liquid, ice, and mixed-phase regions*

Multi-Channel (10-183 GHz) GPM Microwave Imager (GMI):

- *Higher spatial resolution (IFOV: 6-26 km)*
- *Improved light rain & snow detection*
- *Improved signals of solid precipitation over land (especially over snow-covered surfaces)*
- *4-point calibration to serve as a radiometric reference for constellation radiometers*



Combined Radar-Radiometer Retrieval

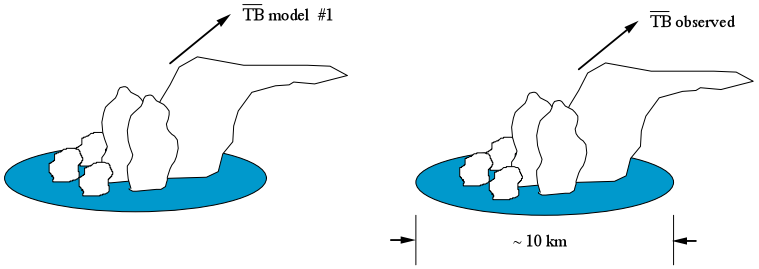
- *DPR & GMI together provide greater constraints on possible solutions to improve retrieval accuracy*
- *Observation-based a-priori cloud database for constellation radiometer retrievals*

GPM Next-Generation Precipitation Products

- Intercalibrated constellation radiometric data (with differences in center frequency, viewing geometry, and resolution reconciled).
  - Converting observations of one satellite to virtual observations of another using non-Sun-synchronous satellite as a transfer standard
  - International working group (NASA, NOAA, JAXA, CONAE, CMA, EUMETSAT, CNRS, GIST, & universities) in coordination with WMO/CGMS GSICS
- Unified precipitation retrievals using a common hydrometeor database constructed from combined DPR+GMI measurements

Optimally matching observed T_b with simulated T_b from an a priori cloud database

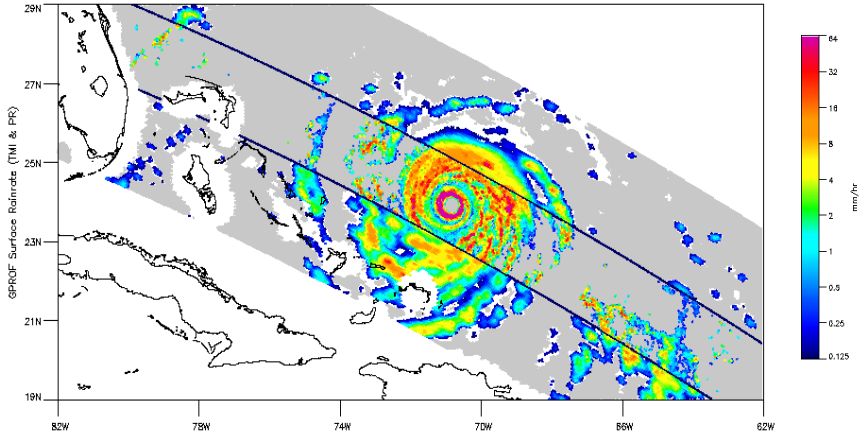
Simulated T_b *Observed T_b*



TRMM uses a model-generated cloud database

GPM uses a DPR/GMI-constrained database

Prototype GPM Radiometer Retrieval



Comparison of TRMM PR surface rain with TMI rain retrieval using an cloud database consistent with PR reflectivity and GMI multichannel radiances

(Kummerow et al., CSU)

GPM Ground Validation

Pre-launch algorithm development & post-launch product evaluation

- Refine algorithm assumptions & parameters -
  Characterize uncertainties in satellite retrievals & GV measurements

Three complementary approaches:

- *Direct statistical validation (surface):*

  - Leveraging off operational networks to identify and resolve first-order discrepancies between satellite and ground-based precipitation estimates

- *Physical process validation (vertical column):*

  - Cloud system and microphysical studies geared toward testing and refinement of physically-based retrieval algorithms

- *Integrated hydrologic validation/applications (4-dimensional):*

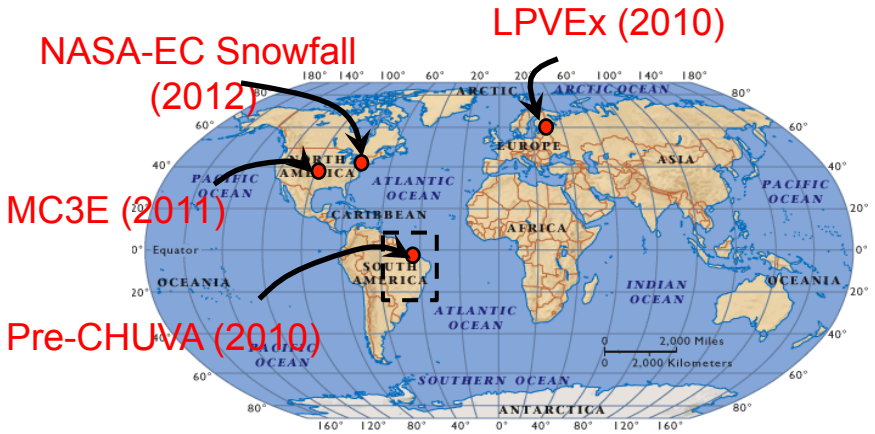
  - Identify space-time scales at which satellite precipitation data are useful to water budget studies and hydrological applications; characterization of model and observation errors

"Truth" is estimated through the convergence of satellite and ground-based estimates

International Science Collaboration

- *Joint field campaigns*
- *National networks and other ground assets (radar, gauges, etc.)*
- *Hydrological validation sites (streamflow gauges, etc.)*

15 Active International Projects

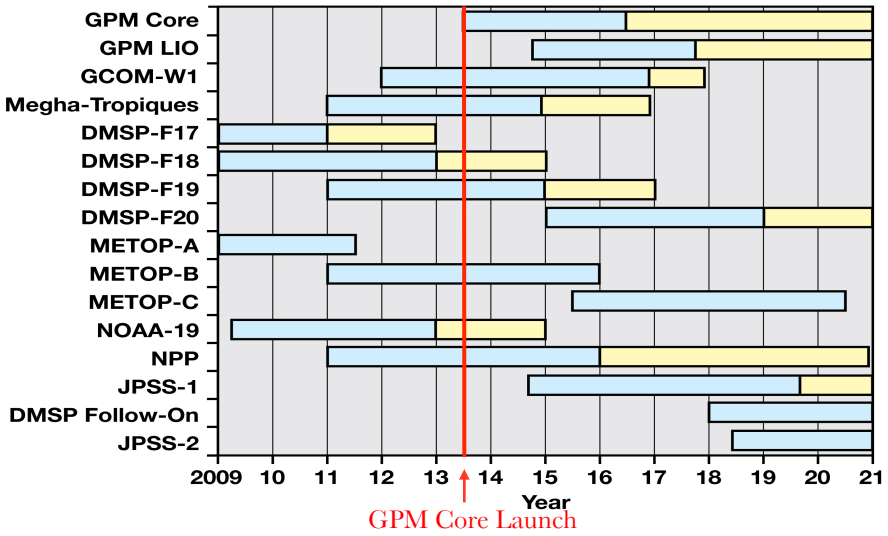


GPM Joint Field Campaigns:

- Joint campaign with Brazil on warm rain retrieval over land in Alcântara, 3-24 March 2010
- Light Precipitation Validation Experiment (LPVEx): CloudSat-GPM light rain in shallow melting layer situations in Helsinki, Finland, Sept-Oct 2010
- Mid-Latitude Continental Convective Clouds Experiment (MC3E): NASA-DOE field campaign in central Oklahoma, Apr-May 2011
- High-Latitude Cold-Season Snowfall Experiment: Joint campaign with Environment Canada on snowfall retrieval in Ontario, Canada, Jan-Feb 2012
- Hydrological validation with NOAA HMT in 2013 (under development)

GPM Constellation Sampling and Coverage

Baseline Constellation Schedule

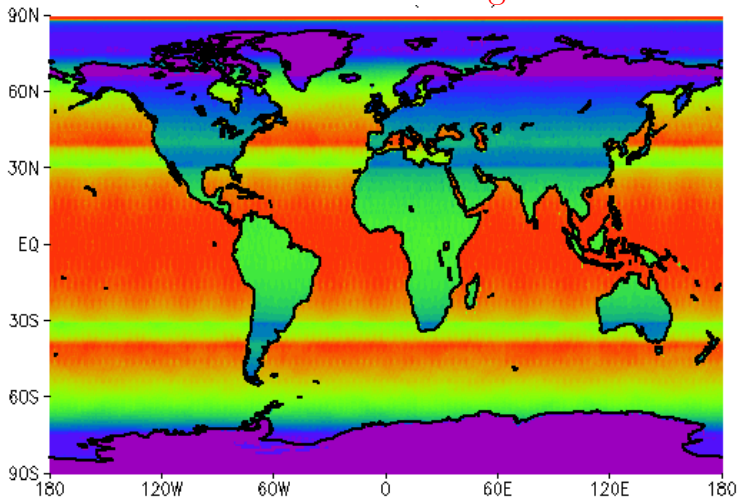


	Average Revisit Time (hr)				
Year	2013	2014	2015	2016	2017
	Land				
Tropics	1.9	1.5	1.5	1.6	2.4
Extratropics	1.3	1.0	1.0	1.2	1.4
Globe	1.6	1.2	1.2	1.4	1.8
	Ocean				
Tropics	3.2	2.6	2.6	2.6	4.9
Extratropics	3.3	2.6	2.6	2.6	3.4
Globe	3.2	2.6	2.6	2.6	4.2
	Land and Ocean				
Tropics	2.8	2.3	2.3	2.3	4.2
Extratropics	2.6	2.1	2.1	2.1	2.7

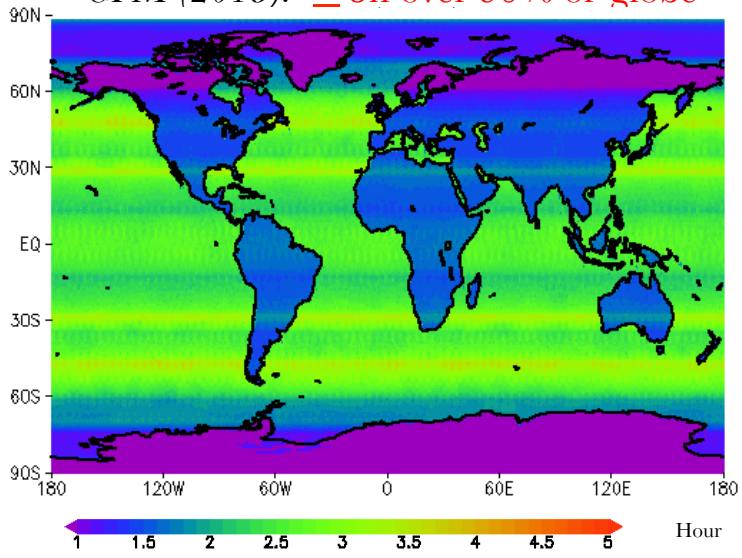
1-2 hr revisit time over land with inclusion of sounders

Current Capability:

≤ 3h over 45% of globe



GPM (2015): ≤ 3h over 90% of globe



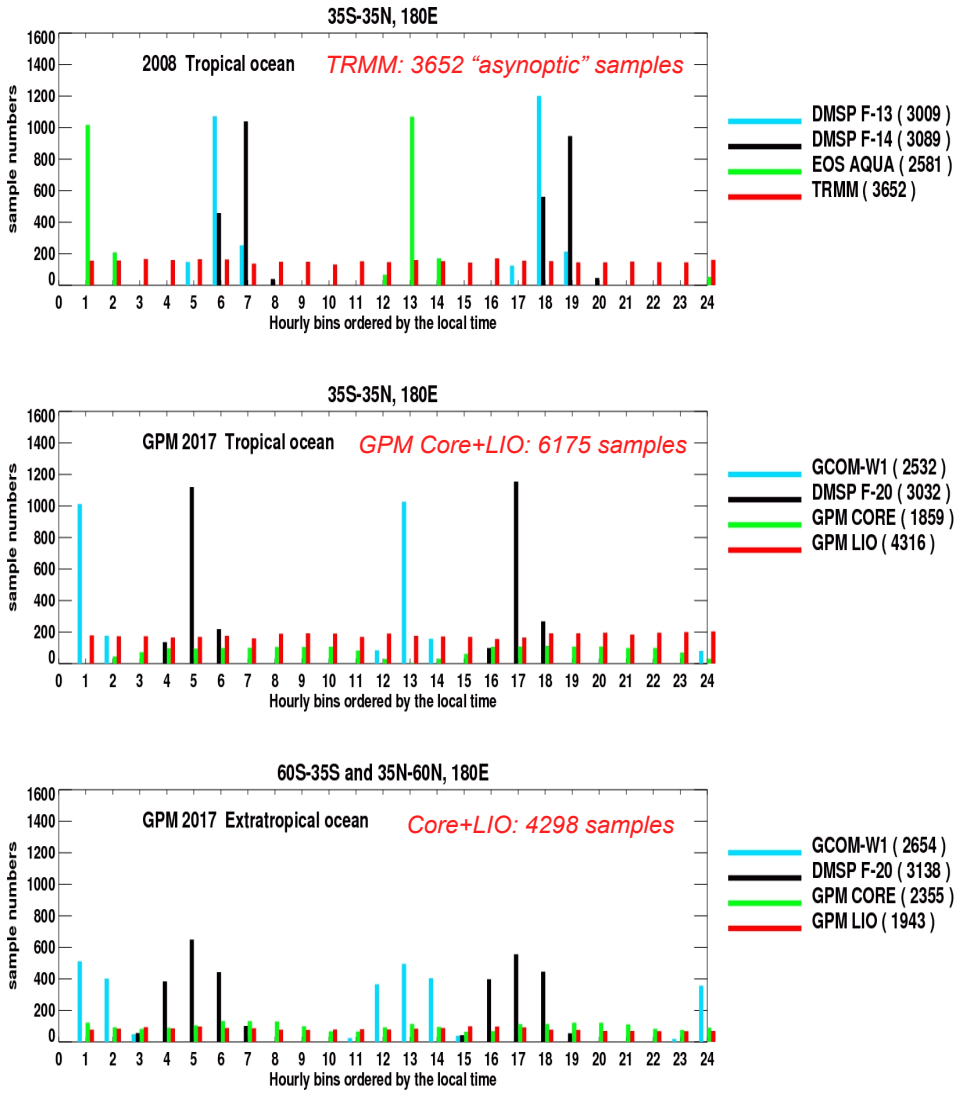
GPM Observations from Non-Sun-Synchronous Orbits

Near real-time observations from the GPM Core and LIO between overpasses by polar orbiters at fixed times of the day for:

- *Intercalibration of polar-orbiting sensors over wide range of latitudes*
- *Near real-time monitoring of hurricanes & midlatitude storms*
- *Improved accuracy of rain volume estimation*
- *Resolving diurnal variability in rainfall climatology*

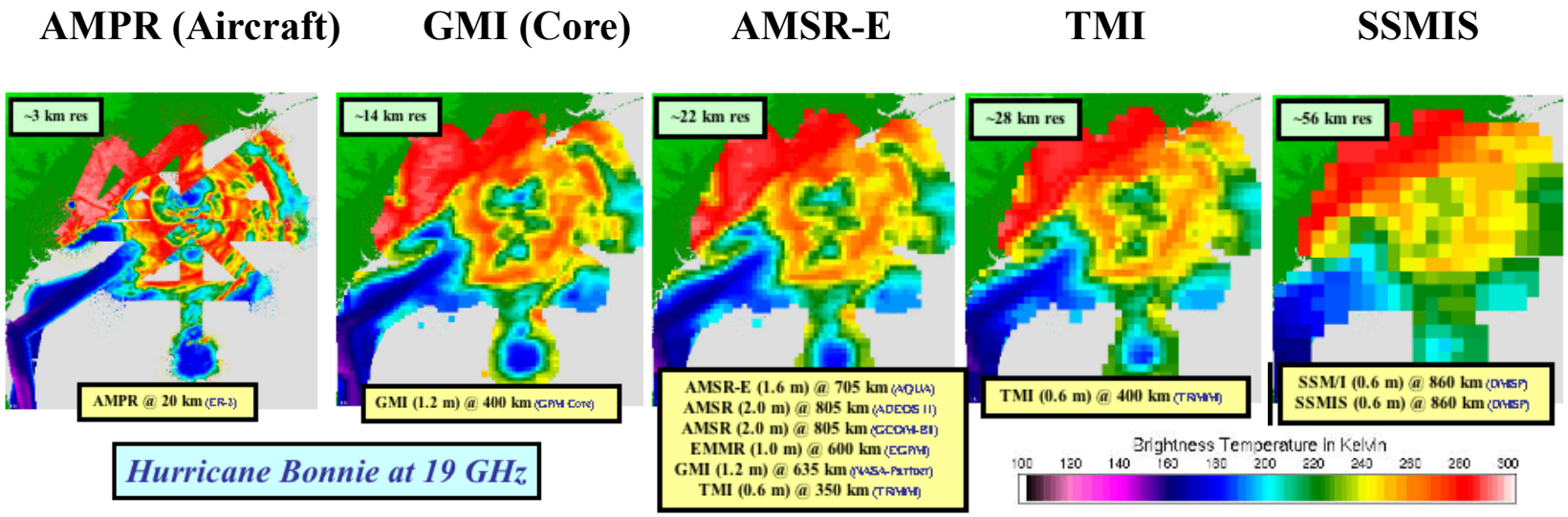
Monthly Samples as a Function of the Time of the Day

(1° x 1° Resolution)



GMI Sensor Resolution

Comparison of GMI resolution with other radiometers



Synthesized Brightness Temperatures (Courtesy of R. Hood)

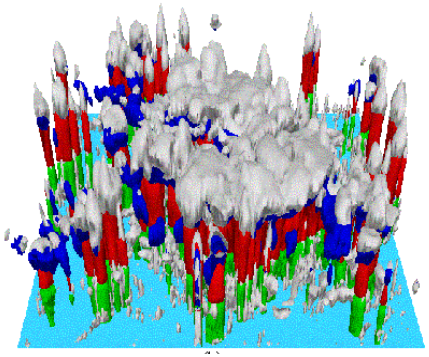
GMI on the Core Observatory altitude of 407 km will offer the highest resolution radiometric imaging data.

GPM Dynamically-Downscaled High-Resolution Product

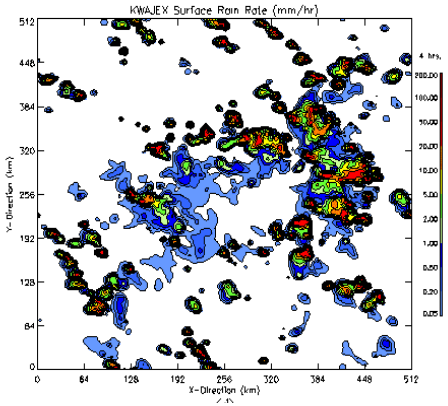
Using CRM to downscale satellite precipitation observations

GPM Observations

Assimilate satellite precipitation data into cloud-resolving model to produce observation-constrained dynamically-balanced precipitation analysis at 1-2 km for hydrological applications



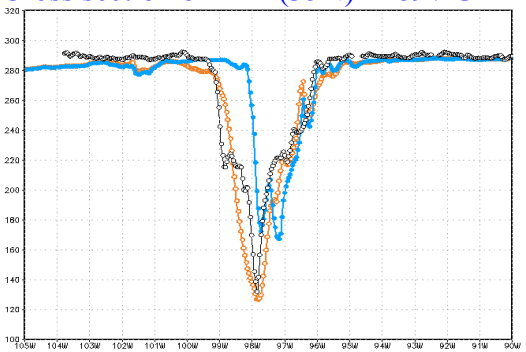
Cloud Resolving Model



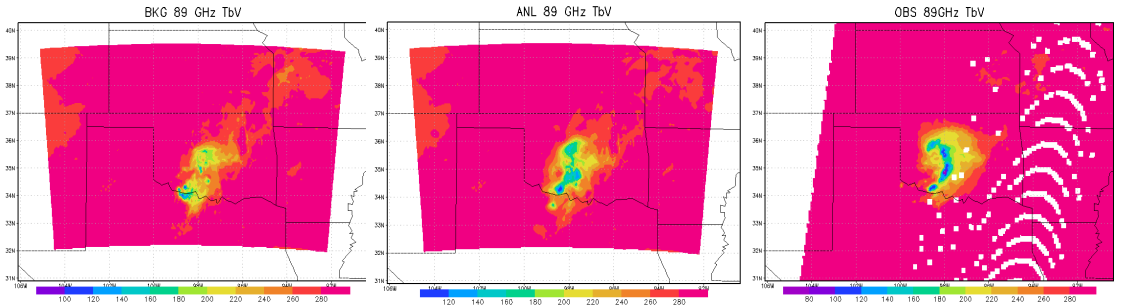
Level-4 Precipitation Analysis

Results from NASA-CSU prototype WRF ensemble data assimilation system assimilating AMSR-E Tb

Cross section of Erin (35N) in 89v GHz



Background (3-h fcst) Analysis (Conv+AMSR-E) Observed Tb 89v



Zupanski et al.

Data Latency

- IFOV intercalibrated Tb and rain products for GMI within 1 hour of data collection
- Merged constellation radiometer precipitation products at several latency levels:

1. Precipitation estimates based on data collected within past 1 hr (fast but incomplete space coverage)
2. Precipitation estimates based on data collected within past 2 hrs
3. Precipitation estimates based on data collected within past 3 hour
4. Precipitation estimates based on data collected within past 6 hours (globally complete)

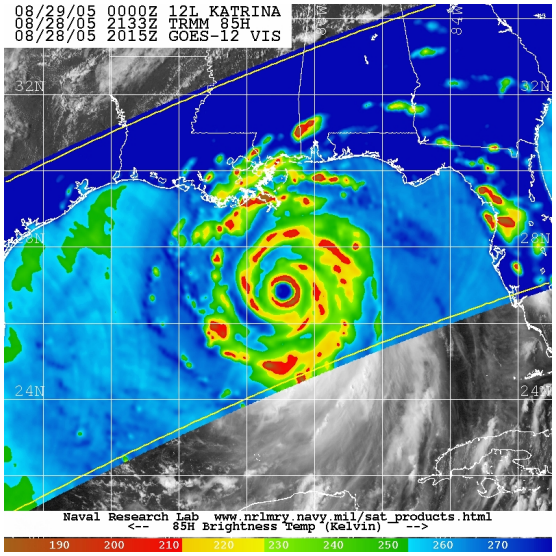
Merged products updated with more observations every hour

GPM Data Products

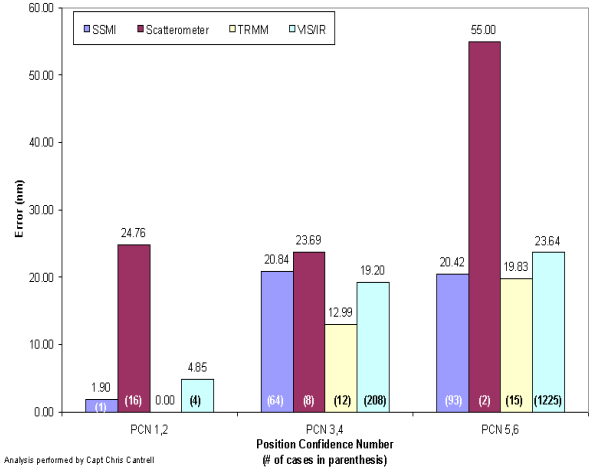
Product Level	Description	Coverage
Level 1B GMI, GMI-2 Level 1C GMI, GMI-2 *Latency ~ 1 hour*	Geolocated Brightness Temperature and intercalibrated brightness temperature	Swath, instrument field of view (IFOV)
Level 1B DPR	Geolocated, calibrated radar powers	Swath, IFOV (produced at JAXA)
Level 1C, partner radiometers	Intercalibrated brightness temperatures	Swath, IFOV
Level 2 GMI, GMI2 *Latency ~1 hour*	Radar enhanced (RE) precipitation retrievals	Swath, IFOV
Level 2 partner radiometers	RE precipitation retrievals from 1C	Swath, IFOV
Level 2 DPR *Latency ~3 hours*	Reflectivities, Sigma Zero, Characterization, DSD, Precipitation with vertical structure	Swath, IFOV (Ku, Ka, combined Ku/Ka)
Level 2 combined GMI/DPR *Latency ~3 hours*	Precipitation	Swath, IFOV (initially at DPR Ku swath and then at GMI swath)
Level 3 Latent Heating (GMI, DPR, Combined)	Latent Heating and associated related parameters	0.1 x 0.1 monthly grid
Level 3 Instrument Accumulations	GMI, partner radiometers, combined and DPR	0.1 x 0.1 monthly grid
Level 3 Merged Product	Merger of GMI, partner radiometer, and IR	0.1 x 0.1 hourly grid
Level 4 Products	Model assimilated data	Fine temporal and spatial scale TBD

Applications of Precipitation Data Products (1/3)

Hurricane Tracking

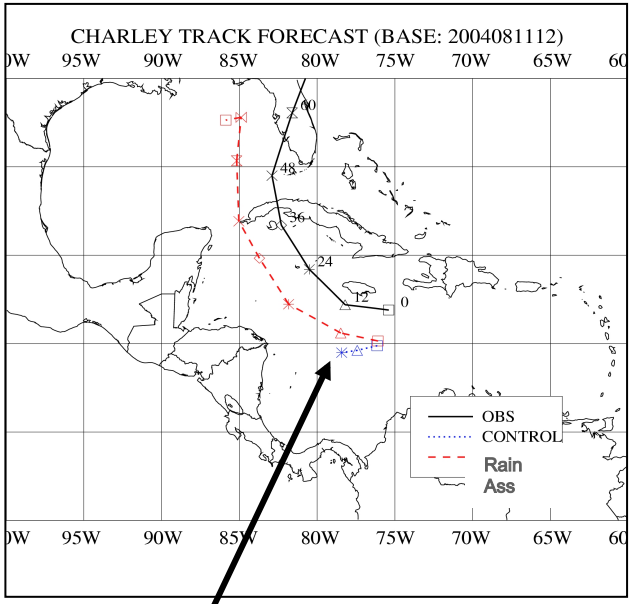


Position Error in Nautical Miles



Numerical Weather Prediction

ECMWF Hurricane Charley track forecasts from analysis 2004081112



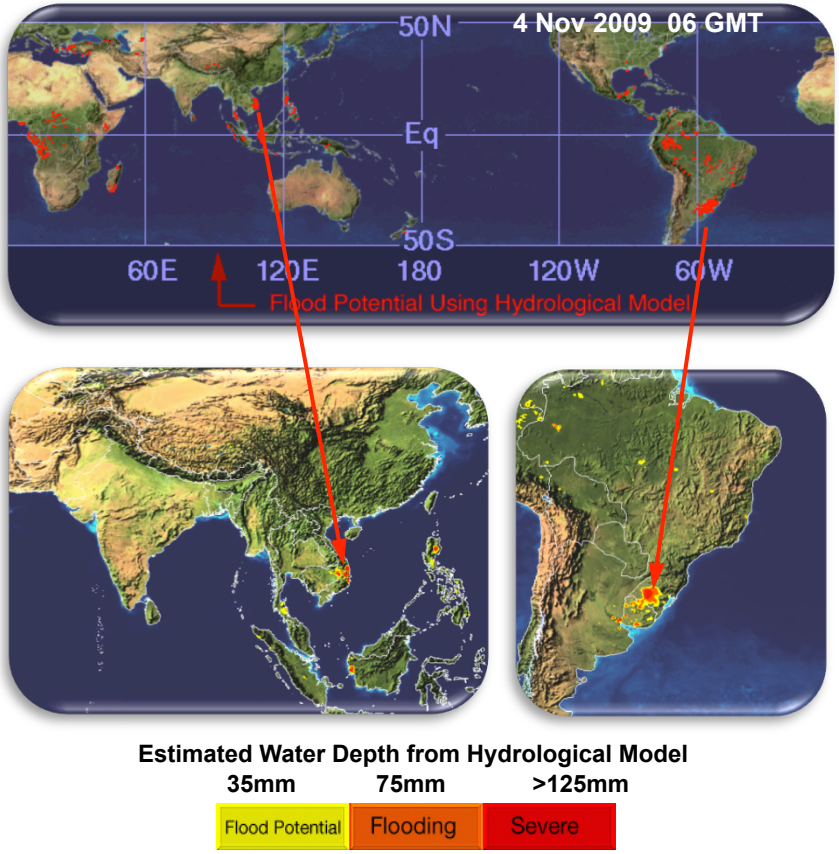
Cyclone disappeared in operational forecast without rain assimilation

Courtesy of P. Bauer/ECMWF

Precipitation observations are in use at ECMWF, NCEP, JMA, and other NWP centers to improve weather forecasting.

Applications of Precipitation Data Products (2/3)

Global Flood Monitoring

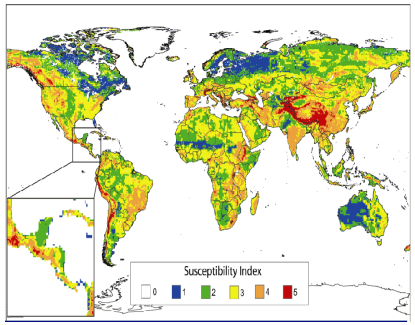


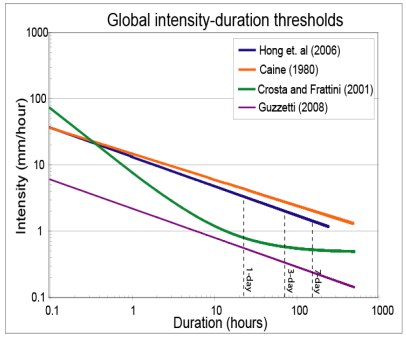
Estimated Water Depth from Hydrological Model

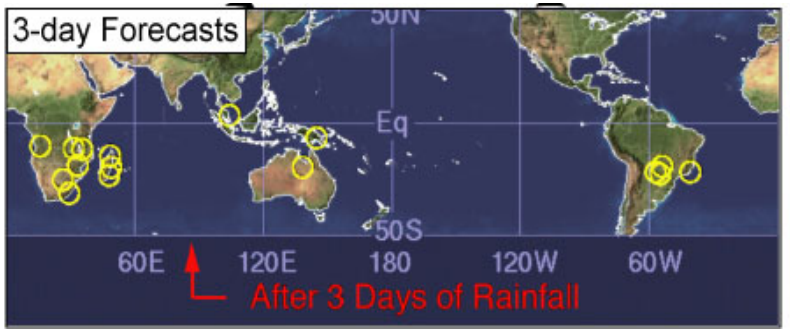
35mm	75mm	>125mm
Flood Potential	Flooding	Severe

On-line real-time estimates of flood areas using satellite rainfall and a hydrological model updated globally, every 3 hrs at 0.25° resolution (http://trmm.gsfc.nasa.gov)

Landslide Hazard Forecasts



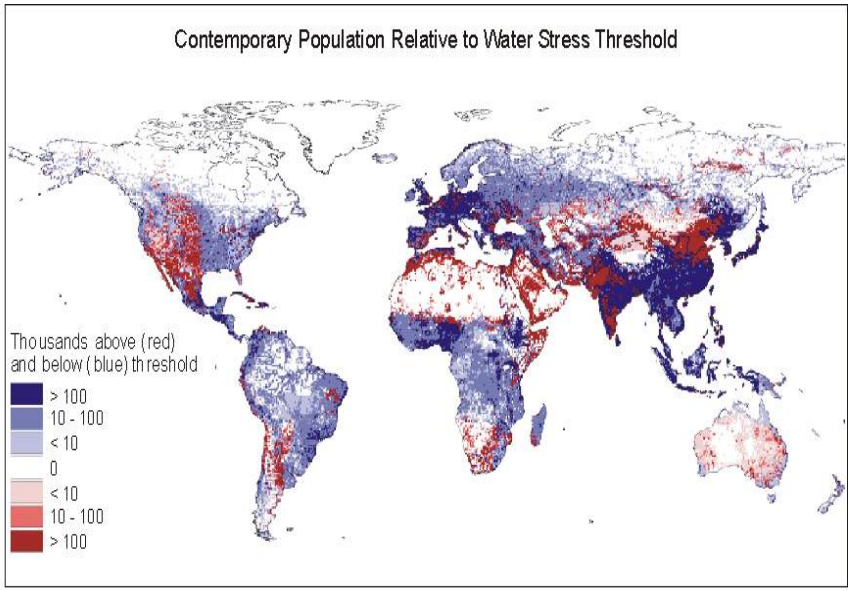




Landslide forecast every 3 hrs based on surface topographic variability, land cover, soil type/texture, drainage density, and rainfall amount (Hong et al.)

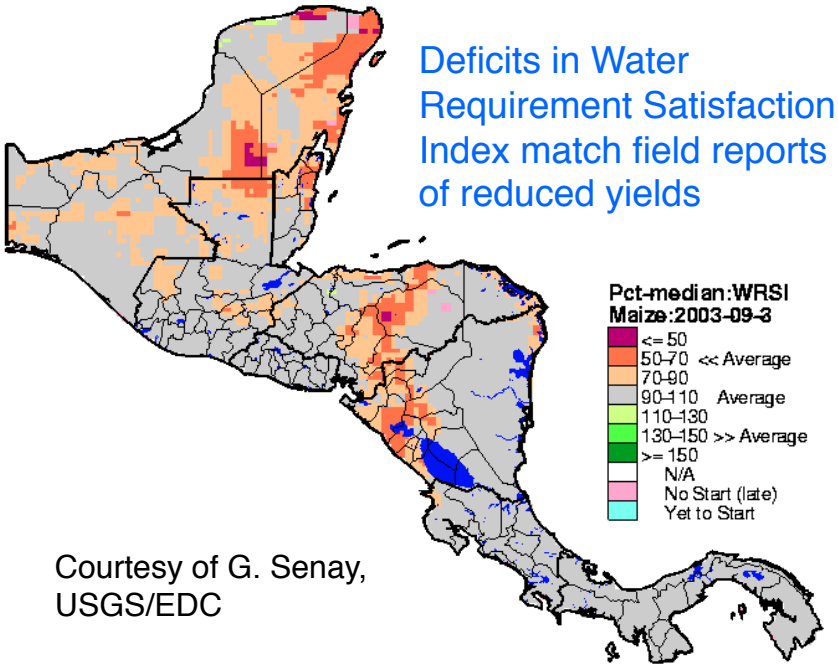
Applications of Precipitation Data Products (3/3)

Freshwater Resource Monitoring



Water stress relative to population growth is a major concern around the world. As the primary source of freshwater, global precipitation data are key to improving freshwater resource monitoring and management on seasonal basis.

Crop Forecasting



Courtesy of G. Senay, USGS/EDC

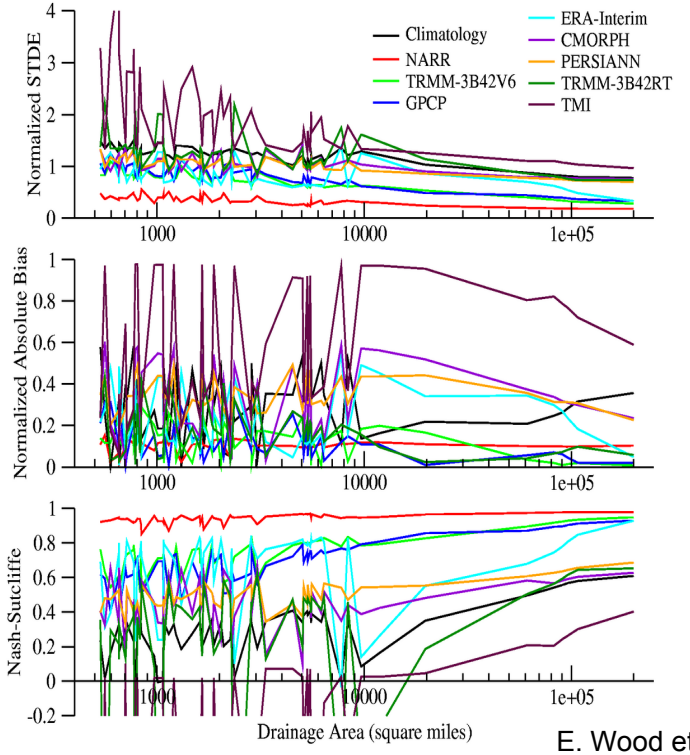
Precipitation data are in use by the USAID/USDA Famine Early Warning System Network (USAID/FEWS-Net) for crop and weather assessment around the world.

Enabling More Effective Use of GPM Data in Applications

Applied research is essential for developing and refining techniques to increase the benefits of precipitation observations in many application areas:

- *NWP, data assimilation, and reanlaysis:*
  - *Advanced assimilation methods to extract maximum information from precipitation data in the presence of forecast model errors*
  - *Improved characterization of precipitation error properties*
- *Hydrological modeling & prediction:*
  - *Identify time-space scales at which satellite rainfall data become useful to water budget studies and hydrological applications*
  - *Characterize uncertainties in hydrologic models and propagation of uncertainties in input data into model forecasts*
  - *Develop downscaling precipitation products for local-scale hydrological modeling and prediction*

STDE, BIAS, and N-S in Daily Streamflow



E. Wood et al.

Current satellite rainfall products have useful skills in river discharge prediction over areas > 10^4 sq. miles

Summary

- GPM is an international satellite mission specifically designed to unify and advance precipitation measurements from a constellation of microwave sensors for scientific research and societal applications.
- GPM is in the implementation phase at NASA and JAXA
- Core Observatory Launch Readiness Date: 21 July 2013
- NASA Precipitation Processing System is currently producing
  - *Prototype intercalibrated L1 products for TMI, SSMI, AMSR-E, SSMIS, & WindSat*
  - *L3 merged global precipitation products using TMI, SSMI, AMSR-E, AMSU, & MetOp in near real-time for research & applications*
- GPM next-generation global precipitation products will build on intercalibrated microwave radiances and unified physical retrievals using a common hydrometeor database consistent with combined radar/ radiometer measurements.
- Ground validation is key to algorithm physics improvement. NASA is conducting a series of joint field campaigns with domestic and international partners to refine algorithm assumptions and parameters.
- Innovative applied research is key to increasing the benefits of precipitation data in many application areas.